

PROCEEDINGS

OF

THE ROYAL SOCIETY.

November 21, 1872.

Sir JAMES PAGET, Bart., D.C.L., Vice-President, in the Chair.

In pursuance of the Statutes, notice was given from the Chair of the ensuing Anniversary Meeting, and the list of Officers and Council proposed for election was read as follows :—

President.—Sir George Biddell Airy, K.C.B., M.A., D.C.L., LL.D. (Astronomer Royal).

Treasurer.—William Spottiswoode, M.A.

Secretaries.— { Prof. George Gabriel Stokes, M.A., D.C.L., LL.D.
{ Prof. Thomas Henry Huxley, LL.D.

Foreign Secretary.—Prof. William Hallowes Miller, M.A., LL.D.

Other Members of the Council.—George James Allman, M.D.; Sir B. C. Brodie, Bart, M.A., D.C.L.; George Busk, F.R.C.S.; Prof. Robert Bellamy Clifton, M.A.; James Fergusson, D.C.L.; Thomas Archer Hirst, Ph.D.; J. Dalton Hooker, C.B., D.C.L., LL.D.; Joseph Prestwich, F.G.S.; Rear-Admiral G. H. Richards, C.B.; Prof. H. Enfield Roscoe, B.A., Ph.D.; Philip Lutley Selater, M.A.; William Sharpey, M.D., LL.D.; Francis Sibson, M.D.; Major-Gen. R. Strachey, R.E., C.S.I.; Isaac Todhunter, M.A.; Sir Charles Wheatstone, D.C.L.

Mr. Abel, Mr. J. Evans, Mr. Hanbury, Mr. Mallet, and Mr. Scott having been nominated by the President, were elected by ballot Auditors of the Treasurer's Accounts on the part of the Society.

The Rev. Thomas Hincks and Prof. T. Rupert Jones were admitted into the Society.

The Presents received were laid on the Table, and thanks ordered for them.

The following communications were read :—

I. "Further Experiments on the more important Physiological Changes induced in the Human Economy by change of Climate." By ALEXANDER RATTRAY, M.D. (Edinb.), Surgeon R.N., H.M.S. 'Britannia.' Communicated by G. BUSK, F.R.S. Received July 1, 1872.

The following observations were made in 1871, during a passage from England to the Cape of Good Hope and back, to verify and extend those published in the 'Proceedings' of this Society for 1869-70-71.

I. *The Effect of Tropical Climate on the Respiration.*

TABLE I. To show:—*First*, that in four healthy adults the spirometric measurement of the lungs gradually rose and fell four times successively in migrating between tropical and temperate climates, and we may therefore conclude that it invariably does so; *second*, that the second rise and fall are the greater, partly owing to an increased range of temperature (3° F.), but chiefly to the freer respiratory action of the skin*.

No.		Near England. Lat. 50° N. March 28. Temp. 57° F.		Near Equator. Lat. 0°. May 2. Temp. 80° F.		Near Cape of Good Hope. Lat. 33° S. June 28. Temp. 56° F.		Near Equator. Lat. 0°. Aug. 29. Temp. 82° F.		Near England. Lat. 51° N. Nov. 2. Temp. 55° F.	
		Chest.	Spirom.	Chest.	Spirom.	Chest.	Spirom.	Chest.	Spirom.	Chest.	Spirom.
	Age.	in.	cub. in.	in.	cub. in.	in.	cub. in.	in.	cub. in.	in.	cub. in.
1.	40 { height 5 ft. 8 in. weight 146 lbs. .	34½	252	34½	275	34½	248	34½	276	34½	246
2.	31 { height 5 ft. 9½ in. weight 166 lbs. .	37½	277	37½	303	37½	273	37½	304	37½	273
3.	30 { height 5 ft. 6 in. weight 154 lbs. .	37¾	284	37¾	300	37¾	283	38¼	306	39	276
4.	22 { height 5 ft. 5¾ in. weight 144 lbs. .	35	216	35	229	35	219	35½	234	36	213
	Average { capacity ...	.....	257	.....	277	.....	256	.....	280	.....	252
	{ rise or fall	.....	.....	.....	20 rise.	.....	21 fall.	.....	24 rise.	.....	28 fall.

The tropico-temperate spirometric range varied in these from 10 to 31, average 23 cubic inches; *i. e.* from 4½ to 11, average 8·7 per cent. of the spirometric measurement of the lungs. The range might have been greater had the thermometric range been so; but it doubtless has its healthy physiological limits. The tropico-frigid spirometric range is probably not much higher, as the bodily temperature in cold regions is usually maintained by food, fires, &c. at about the same standard as in the temperate zone. This altered spirometric measurement is permanent, *i. e.* lasts as long as the residence in the new zone.

* This and subsequent facts appear to warrant a conclusion formerly expressed, *viz.* that one effect of frequent change of climate is to increase, within certain bounds, the vicarious capabilities of excreting organs.

Table II. shows :—*First.* That this law prevails between the ages of $14\frac{1}{2}$ and 62, and therefore doubtless at all ages.

Second. That the rise and fall are greatest at the prime, and decrease towards either extreme of life.

Third. That at all ages, and for the same reason, the rise and fall are greatest in those of largest frame and most full-blooded.

Fourth. That for the same reason this rise and fall are greater, *ceteris paribus*, above than under puberty (marked *), and subsequently increase with the growth of the frame.

Fifth. That the normal expansion of the lungs and chest from growth only lessens slightly the spirometric reduction under cold, which often falls below its original standard.

Sixth. That after mid age the rise and fall, like the spirometric measurement itself, diminish with the progressive decay of the frame (cases 68 to 73).

Seventh. That in extreme old age (case 74) the shrivelling and less vascular lungs, skin, body, diminishing chest (cases 68, 71), respiratory and circulatory functions lessen and finally counterbalance the law.

Eighth. That obesity, *i. e.* an increased bulk of body, does not interfere with the last-mentioned effect of advancing age (case 69).

Ninth. That the rise and fall are not materially interfered with by an ordinary catarrh (case 55) or asthma (case 56).

The only exceptions to the law among the 47 cadets were (case 16) a suspicious chest, which gave no primary increase under heat; and case 41, which, instead of decreasing under cold, increased by 4 cubic inches by unusually rapid chest expansion from growth.

TABLE II. Climatic Spirometric range at different ages.

No.	Age.	South Temperate Zone. Lat. 35° S.; Temp. 55°-65° F. July 16, 1871.				Tropics. Near Equator; Temp. 82° F. Aug. 31, 1871.				North Temperate Zone. Lat. 50° N.; Temp. 52°-56° F. Nov. 2, 1871.			
		Weight.	Height.	Chest.	Spirom.	Weight.	Height.	Chest.	Spirom.	Weight.	Height.	Chest.	Spirom.
1*.	14.6	88	4 4	28 $\frac{1}{2}$	111	89	4 7 $\frac{1}{2}$	28 $\frac{3}{4}$	115	95	4 8 $\frac{1}{4}$	29	111
2*.	14.8	118	5 3 $\frac{3}{4}$	32 $\frac{3}{4}$	186	119	5 4	33	202	120	5 4 $\frac{1}{4}$	33	195
3*.	14.11	99	5 2	30 $\frac{1}{2}$	147	100	5 2 $\frac{3}{4}$	30 $\frac{1}{2}$	156	101	5 2 $\frac{3}{4}$	30 $\frac{1}{2}$	141
4*.	15.1	97	5 2 $\frac{1}{2}$	30	171	100	5 2 $\frac{3}{4}$	30 $\frac{1}{4}$	183	101	5 3	30 $\frac{1}{4}$	163
5*.	15.3	115	5 4	33	180	116	5 4 $\frac{1}{2}$	34	195	115	5 4 $\frac{1}{2}$	34 $\frac{1}{2}$	186
6*.	15.4	119	5 5 $\frac{1}{2}$	32 $\frac{3}{4}$	189	116	5 6	33 $\frac{1}{2}$	201	121	5 6 $\frac{1}{4}$	33 $\frac{1}{2}$	192
7*.	15.4	98	5 4 $\frac{1}{4}$	30	174	98	5 4 $\frac{1}{2}$	30	186	95	5 4 $\frac{1}{2}$	30	165
8.	15.6	122	5 5 $\frac{1}{2}$	32	199	124	5 6	32 $\frac{3}{4}$	207	125	5 6 $\frac{1}{4}$	32 $\frac{3}{4}$	198
9*.	15.6	121	5 4	31 $\frac{1}{4}$	141	109	5 3 $\frac{1}{4}$	31 $\frac{1}{4}$	165	118	5 4 $\frac{1}{4}$	31 $\frac{1}{4}$	156
10*.	15.6	96	4 11	30 $\frac{1}{4}$	141	94	4 11 $\frac{1}{2}$	30 $\frac{1}{2}$	153	97	4 11 $\frac{1}{2}$	30 $\frac{1}{2}$	141
11*.	15.6	100	5 3 $\frac{1}{4}$	30 $\frac{3}{4}$	158	95	5 4	30 $\frac{3}{4}$	168	98	5 4	30 $\frac{3}{4}$	162
12*.	15.6	122	5 5 $\frac{1}{2}$	33 $\frac{1}{4}$	186	120	5 6	33 $\frac{1}{4}$	201	119	5 6	33 $\frac{1}{4}$	195
13*.	15.6	99	4 9 $\frac{1}{2}$	30	150	88	4 10 $\frac{1}{4}$	30 $\frac{1}{2}$	165	92	4 10	31 $\frac{1}{4}$	162
14.	15.7	153	5 9	36 $\frac{1}{4}$	237	150	5 8 $\frac{3}{4}$	36 $\frac{1}{2}$	261	158	5 9 $\frac{1}{2}$	37	256
15.	15.7	122	5 8 $\frac{3}{4}$	32 $\frac{3}{4}$	213	118	5 9	33 $\frac{1}{2}$	240	118	5 9	34	225
16*.	15.7	105	5 4	28 $\frac{3}{4}$	162	100	5 3 $\frac{1}{4}$	28 $\frac{3}{4}$	162	106	5 3 $\frac{1}{2}$	29 $\frac{1}{4}$	159
17.	15.7	141	5 7	35 $\frac{1}{2}$	226	138	5 7	35 $\frac{1}{2}$	237	137	5 7	35 $\frac{1}{2}$	220
18*.	15.8	110	5 4	30 $\frac{1}{4}$	168	105	5 4	31 $\frac{1}{4}$	175	106	5 4 $\frac{1}{2}$	31 $\frac{1}{4}$	165

TABLE II. (continued).

No.	Age.	South Temperate Zone. Lat. 35° S.; Temp. 55°-65° F. July 16, 1871.				Tropics. Near Equator; Temp. 82° F. Aug. 31, 1871.				North Temperate Zone. Lat. 50° N.; Temp. 52°-56° F. Nov. 2, 1871.						
		Wei ht.		Height.	Chest.	Spirom.	Weight.	Height.	Chest.	Spirom.	Weight.	Height.	Chest.	Spirom.		
		lbs.	ft. in.	in.	cub. in.	lbs.	ft. in.	in.	cub. in.	lbs.	ft. in.	in.	cub. in.			
19.	15'8	150	5	9½	36	216	149	5	9½	36½	234	156	5	9½	36½	204
20.	15'8	139	5	9½	35½	228	141	5	9½	35½	256	144	5	10	35½	243
21.	15'8	123	5	4	35½	216	126	5	4½	35½	231	127	5	4½	35½	213
22*.	15'8	121	5	6½	34½	219	120	5	7	34½	231	121	5	7	34½	225
23*.	15'9	132	5	5½	35½	228	132	5	5½	35½	240	130	5	5½	35½	216
24.	15'9	136	5	5½	36	216	137	5	6½	36½	237	138	5	6½	37	231
25.	15'9	161	5	11	36½	252	160	5	11	36½	264	160	5	11	36½	246
26*.	15'9	115	5	5½	33½	189	114	5	5½	33½	207	119	5	5½	33½	198
27*.	15'9	131	5	8½	33	192	125	5	8½	33	198	127	5	9½	33½	192
28.	15'9	137	5	3½	35½	222	141	5	3½	36½	240	133	5	3½	36½	222
29*.	15'9	109	5	3	32	168	108	5	2½	33	197	112	5	3½	33½	186
30.	15'10	125	5	6½	32	183	124	5	6½	33½	189	123	5	6½	33½	180
31.	15'10	110	5	5	32½	192	109	5	5½	33	204	114	5	5½	33½	186
32.	15'11	138	5	7½	36½	219	136	5	7½	36½	237	135	5	8	36½	210
33.	16'0	141	5	9½	35½	237	137	5	9½	35½	248	139	5	9½	35½	225
34.	16'0	146	5	10½	36	252	144	5	10½	36½	267	147	5	11	36½	258
35*.	16'1	116	5	4½	33½	186	112	5	4½	34½	204	114	5	5½	34½	192
36.	16'1	140	5	8	35½	207	142	5	8	36	219	141	5	8	36½	198
37.	16'2	137	5	2½	35½	213	135	5	2½	35½	225	131	5	2½	36	219
38*.	16'2	111	5	1	34	189	108	5	1½	34	208	114	5	2	34½	201
39*.	16'2	113	5	7½	32	189	111	5	7½	32½	195	113	5	7½	32½	180
40.	16'2	131	5	8½	34½	228	126	5	8	34½	240	129	5	9	35	234
41*.	16'3	102	5	3½	30½	150	99	5	4	30½	156	99	5	4½	31	160
42*.	16'3	103	5	2½	29½	147	107	5	2½	29½	153	114	5	3½	30	144
43.	16'3	152	5	10½	35½	247	150	5	10½	36	252	156	5	10½	36½	231
44*.	16'5	112	5	2½	34	165	114	5	3	34½	180	119	5	3	34½	171
45.	16'5	136	5	5½	35½	205	136	5	5½	35½	212	131	5	6½	35½	192
46*.	16'6	107	5	3½	31½	172	105	5	4	32	183	109	5	4	32½	168
47.	16'8	130	5	7½	32½	196	127	5	7½	32½	228	128	5	7½	32½	207
48.	17'5	150	5	7	36½	213	145	5	7	36½	228	149	5	7½	36½	219
49.	18'2	148	5	4½	36	222	143	5	4½	36½	234	143	5	4½	36½	219
50.	18'8	149	5	8	35½	261	145	5	8	35½	267	146	5	8½	35½	249
51.	19'7	164	5	8	38½	264	162	5	9	38½	282	158	5	9	38½	264
52.	20'1	158	5	11½	37½	258	157	5	11½	37½	267	158	5	11½	37½	249
53.	20'6	142	5	6	34½	216	137	5	6	34½	234	141	5	6	35½	198
54.	20'6	150	5	10½	35½	264	143	5	11	36	300	145	5	11	36½	288
55.	21'5	161	5	8	35½	210	156	5	8	35½	225	160	5	8	35½	213
56.	21'9	172	5	9½	38	243	172	5	9½	38	246	174	5	9½	38	240
57.	22'2	152	5	10	35	256	148	5	10	36	264	149	5	10	36	236
58.	22'2	152	5	7½	36½	228	152	5	7½	36½	243	156	5	7½	36½	222
59.	22'2	144	5	5½	35	219	143	5	6	35½	234	144	5	6½	36	213
60.	23'2	139	5	6½	34½	201	130	5	6½	34½	228	135	5	6½	34½	207
61.	30'0	154	5	6	37½	283	154	5	6	38½	306	156	5	6	39½	276
62.	31'0	166	5	9½	37½	273	166	5	9½	37½	304	164	5	9½	37½	273
63.	40'0	146	5	8½	34½	248	148	5	8½	34½	276	145	5	8½	34½	246
64.	40'0	...	...	...	...	...	...	...	...	...	208	...	...	...	...	198
65.	41'0	...	...	...	...	...	...	...	...	...	196	...	...	...	...	186
66.	42'0	...	...	...	...	...	...	...	...	...	247	...	...	...	...	222
67.	43'0	...	...	...	...	...	...	...	...	...	207	...	...	...	...	204
68.	45'0	145	5	7	38½	234	141	5	7	38½	239	140	5	7	38	231
69.	45'0	168	5	8½	38½	237	162	5	8½	38½	246	160	5	8½	38½	234
70.	46'0	...	...	...	...	...	...	...	...	...	249	...	...	...	...	226
71.	47'0	152	5	8½	39	270	152	5	8½	38½	273	154	5	8½	38½	270
72.	47'0	152	5	9½	36½	216	148	5	9½	36½	224	149	5	9½	36½	213
73.	48'0	163	5	10	38½	186	164	5	10	38½	195	161	5	10	38½	177
74.	62'0	140	5	7½	35½	210	139	5	7½	35½	201	138	5	7½	35½	195

TABLE III. shows that, as with latitude, change of altitude, *i. e.* temperature, causes a rise and fall in the spirometric measurement.

Place &c.			Spirometric measurement of lungs.
			cubic inches.
A. R., at. 40. Ascension. Lat. 8° S.	Aug. 14. Level of Sea.	Temp. 75° F. ...	266
	Aug. 14. Green Mountain (2000 feet high).	Temp. 67° F. ...	249
	Aug. 15. „	Temp. 65° F. ...	243

This gives a difference of 18 cubic inches from a 10° F. reduction of temperature. Summer heat and winter cold in temperate latitudes, and also the atmosphere of artificially heated or cooled rooms or wards, have corresponding results.

That this spirometric law of climate has little except perhaps a secondary and minor connexion with an increase or decrease in the capacity of the bony chest is shown :—

1st. By the usual absence of any change in the circumference of the adult chest when the rise and fall are greatest (Table I., cases 1 and 2).

2nd. By the slight interference of growth of chest with the manifestations of the law, both in the adult (Table I., cases 3 and 4), and especially the cadets (Table II., cases 1 to 47) and junior officers (Table II., cases 48 to 60).

The spirometric measurement of the lungs is probably occasionally increased by actual chest expansion when an increased respiratory function is suddenly required in health or disease. But this is exceptional; and in emergencies, in cold and warm climates alike, this result is usually effected in a more natural and easier way, *viz.* by increasing the frequency of the respiration.

The only theory that will satisfactorily explain this tropical increase in the spirometric measurement of the lungs, with its peculiarities, and correlate it with other apparently opposed respiratory phenomena, such as slower and gentler inspiration, and also the *post mortem* lightness of the lungs observed by Francis and Parkes, is that it arises not from enlargement of the chest, but merely from a change in the relative quantity of blood and air in the lungs. The law of the lungs is merely a sequel of the greater law of the circulation, by which the entire blood-current is redistributed, and either attracted surfaceward by heat or driven inward by cold. The lungs, unaltered in size, contain less blood, actually and relatively, and more air in the tropics; they are less vascular, but more inflated. The oscillation in the relative proportion of blood and air follows an inverse ratio, the one rising, for an obvious reason, as the other falls. It is the rise or fall in the air, and not in the blood, which corresponds with the rise and fall of temperature. Blood is the dis-

placing, and air the displaced agent. It is in the blood that the fluctuation originates: when heat attracts this surfacewards, the amount drawn from the lungs is replaced by an equivalent bulk of air; under cold, which repels the blood inward, the air is again displaced by an equivalent of blood*.

Contrary to previous conviction, based on limited experiment, this variation in the spirometric measurement of the lungs is no index of the effect of change of climate on the *ordinary breathing*. Table III. shows that the latter, instead of deepening by heat like the former, does the reverse, and becomes *gentler*. As part of the same general physiological process, reflection points to this as the more likely sequel, and reconciles these apparently conflicting though allied phenomena.

TABLE IV.†

	South temperate zone. Lat. 35°. Temp. 54° F.	Tropics. Near Equator. Temp. 82° F.
A. R., æt. 40. Average of 12 ordinary respirations. 3 P.M. }	cubic inches. 14.54	cubic inches. 13.25

Thus my respirations averaged $14\frac{1}{2}$ cubic inches in 54° F., and only $13\frac{1}{4}$ cubic inches in 82° F., *i. e.* less than 1.29 cubic inch. So that even if the respirations remained at $15\frac{1}{2}$ per minute, this alone would reduce the air used by 28,792 cubic inches, = 16.66 cubic feet, per day.

TABLE V. confirms former observation that respiration is *slower* in the tropics.

	Lat. 33° S. Temp. 56° F.	Equator. Temp. 82° F.	Lat. 53° N. Temp. 54° F.
Average of 15 { Rattray, æt. 40 minutes at { Downer, æt. 31 3 P.M. { Willecox, æt. 20 Averages.....	No. 16 17 19 17.3	No. 15.6 16.6 16.2 16.1	No. 16.5 18.5 17.5 17.5

* This derivative action of heated air on the lungs corresponds to that of other derivatives, *e. g.* a hot bath increases their spirometric measurement by several cubic inches; so does a sordorific dose of Dover's powder. Ordinary slow and prolonged exercise does the same by drawing blood to the functionally active muscles; and under violent exercise and a perspiring skin it rises from 10 to 15 cubic inches, even when the second result is taken in the evening, when the reduced temperature should have lessened it in accordance with the law of climate. This effect of exercise, however, is not so marked in the tropics as in temperate regions.

† This experiment was made by means of an easily inflated bladder, from which the air was measured by a graduated glass cylinder.

Thus in three adults it fell from an average of 17·3 per minute in 56° F. to 16·1 in 82° F., and again rose to 17·5 in 53° F. To close observation it was perceptibly slower and gentler*. However, as in temperate so in warm regions, the frequency of the respiration varies with the activity of the skin, purity of the blood, and need of the tissues for oxygen. Thus my tropical respirations ranged from 11 to 15, average 12·74 per minute; the range for the temperate zone being 13½ to 18, average 15·68.

These three well-marked tropical phenomena, viz. diminished lung vascularity, slower respiration, and gentler breathing, are closely related, and together indicate reduced lung work, the reverse for the temperate zone marking an increased function—thus proving that this varies with temperature, as with age, sex, height, &c. Their aggregate results vary with individuals, and perhaps races; but the following is a fair average of the reduction in the air respired and carbon excreted:—

TABLE VI.

		Cubic inches of air per respi- ration from Table IV.	Number of re- spirations per minute, from Table V.	Cubic inches of air respired per minute.
A. R., æst. 40.	Tropics, temp. 82° F.	13·25	15·6	195·69 †
	Temp. zone, temp. 54° F....	14·54	16·5	239·91

Difference per minute in favour of a temperate climate ... 44·22 cubic inches.

„ hour „ 2653·20 „

„ day „ 63676·80 „

18·43 per cent. = 36·85 cubic feet ‡.

Thus 239 cubic inches of air were respired per minute in the temperate zone, against 195 cubic inches in the tropics, = a difference of 44 cubic inches per minute, or 36·85 cubic feet per day, = 18·43 per cent.

Then, taking 10 oz. as the average amount of carbon thrown off by the lungs in the temperate climate of England §, this reduction of 18·43 per cent. gives 8·157 oz. as the amount for the tropics. The pulmonary excretion of watery vapour is doubtless correspondingly diminished.

* The experiments further proved that, like the circulation (pulse), the respiration increases towards infancy. Is the latter function, though actually less, relatively greater then from the rapid renewal and deoxidation of tissue and food?

† Corrected for heat in accordance with Dalton and Gay Lussac's law, the difference here being 27° F.

‡ Former calculation (Proceedings, June 16, 1870) made this as 27·81 cubic inches less of air per minute, = 10·9 per cent. = minus 1·1028 oz. of carbon per day. But this was based on limited data, in which the respiration was inaccurately fixed, and its depth calculated not from direct observation, but from the increased spirometric measurement of the lungs.

§ Mean of three estimates by Lavoisier and Seguin, Davy, and Allen and Pepys.

But this and the 1·843 oz. less carbon are perhaps partly excreted by the vicariously active skin and liver; but how far has yet to be determined. But it must be remembered that less carbon has usually to be eliminated in the tropics, both from the reduced and often altered ingesta, and lessened brain and body-tissue waste.

II. *The Effect of Tropical Climate on the Bodily Development.*

The following experiments prove that tropical climate, *per se*, interferes with the normal growth of the body. During the voyage forty-eight cadets, of the impressionable age of 14½ to 17, were weighed and measured in height six times at intervals of sixty days, *i. e.* after four successive changes of climate, their diet being abundant, fresh, and healthy. If lads stop growing, and still more if they lose flesh, it proves that some unhealthy influence is at work.

TABLE VII. shows:—*First*, that tropical heat interferes much with the bodily growth and development, as indicated by the *weight*, retarding it in most, and stopping it in some; *second*, that temperate climates have an opposite influence; *third*, that a second exposure to heat increases its wasting effect, and also lessens the subsequent building-up results of cold.

Exp.		Gain in weight.		Stationary in weight.		Loss in weight.	
		Per cent.	Average gain. lbs.	Per cent.	lbs.	Per cent.	Average loss. lbs.
1.	Effect of <i>heat</i> : 60 days in the tropics, temp. 70°–82° F....	56·26	3·81	14·58	...	29·16	3·07
2.	Effect of <i>cold</i> : 60 days in the S. Temp.Zone, temp. 55°–70° F.	93·75	6·35	6·25			
3.	Effect of <i>heat</i> : 60 days in the tropics, temp. 70°–82° F.	2·17	2·0	2·17	...	95·66	4·61
4.	Effect of <i>cold</i> : 60 days in the N.Temp.Zone, temp. 52°–70°	86·96	4·0	6·52	...	6·52	2·0
5.	Effect of <i>cold</i> : 60 days in the N.Temp.Zone, temp. 32°–50°	93·48	5·91	6·52			

The effect of climate on growth in height is somewhat different. As a rule this should be regular, though oftener, so to speak, *per saltum*, than with weight.

TABLE VIII. shows :—*First*, that tropical are more favourable to growth in height than temperate climates ; *second*, that the influence of both is more decided on a second than a first exposure.

Exp.		Gain in height.		Stationary in height.	
		Per cent.	Average gain. inches.	Per cent.	Average inches.
1.	Effect of <i>heat</i> : 60 days in the tropics, temp. 70°–82° F.	68·75	0·64	31·25	
2.	Effect of <i>cold</i> : 60 days in the S. Temp. Zone, temp. 55°–70° F.	46·81	0·5	53·19	
3.	Effect of <i>heat</i> : 60 days in the tropics, temp. 70°–82° F.	69·57	0·52	30·43	
4.	Effect of <i>cold</i> : 60 days in the N. Temp. Zone, temp. 52°–70° F.	41·31	0·29	58·69	
5.	Effect of <i>cold</i> : 60 days in the N. Temp. Zone, temp. 32°–50° F.	23·91	0·43	76·09	

As heat thus makes the young shoot rapidly, it might be deemed favourable to the bodily development ; but as the results are so different from those in Table VII., they cannot be taken as a true index of the healthiness of tropical climates, and must be studied with those of weight.

An increasing weight, with either an increasing (Table IX. col. 1) or even stationary height (col. 2), is a healthy sign ; but if youths who should be growing in weight and height remain stationary (col. 3), or remain of the same height but lose weight (col. 4), or even grow in height while weight does not increase (col. 5), and still more if height increases while weight loses (col. 6), their physique must be deteriorating.

TABLE IX., with its two columns of averages contrasting these favourable and unfavourable signs, gives results similar to Table VII.; and shows :—*first*, that tropic heat is unfavourable to the bodily development ; *second*, that cold climates are favourable to it ; *third*, that the impairing effect of a second is greater than that of a first exposure to heat ; *fourth*, that each successive exposure to heat lessens still further the bracing influence of cold.

Exp.		1.	2.	Per cent.	3.	4.	5.	6.	Per cent.
		H. + W. +	H. 0 W. +		H. 0 W. 0	H. 0 W. -	H. + W. 0	H. + W. -	
1.	Effect of <i>heat</i> : 60 days in the tropics, temp. 70°–82° F.	19	7	54·1	2	7	6	7	45·8
2.	Effect of <i>cold</i> : 60 days in the S. Temp. Zone, temp. 55°–70° F.	21	24	95·7	1	0	1	0	4·2
3.	Effect of <i>heat</i> : 60 days in the tropics, temp. 70°–82° F.	1	0	2·1	0	13	1	31	97·8
4.	Effect of <i>cold</i> : 60 days in the N. Temp. Zone, temp. 52°–70° F.	15	25	86·9	1	1	2	2	13·0
5.	Effect of <i>cold</i> : 60 days in the N. Temp. Zone, temp. 32°–50° F.	10	33	93·4	2	0	0	1	6·52

Both the number who grew and the amount of increase were thus least in the tropics. These detrimental fluctuations necessarily affect both body and brain. If, therefore, we would produce strong, healthy, long-lived officers and seamen, fit for any work or climate, we should not send them unnecessarily to warm regions while as yet undeveloped lads.

The following are the chief results and inferences of these experiments:—

- 1st. The primary effect of great changes of climate is on the circulation, the blood being drawn surfaceward by heat and driven inward by cold.
- 2nd. The secondary and local results are an increase or decrease in the vascularity and function of the various tissues and organs of the entire body—the external increasing under heat, internal under cold, and *vice versâ*.
- 3rd. Hence in the tropics the vascularity of the adult lungs is reduced by an average of 12 or 13 fluid oz.; their spirometric measurement by an average of 23 cubic inches; their function by 18·43 per cent., *i. e.* the use of 36·85 cubic feet less of air daily, excretion of 1·84 oz. less carbon, and 6·57 per cent. less of watery vapour.
- 4th. Hence, also, the nephritic vascularity and secretion are reduced in the tropics by 17½ per cent., and those of the skin increased by 24 per cent.
- 5th. In unison with the respiration the circulation is more languid in the tropics, as indicated by the reduced (several beats) and perhaps less forcible pulse.
- 6th. Notwithstanding the reduced circulatory and respiratory functions, and increased cutaneous exhalation, the temperature of the surface, and perhaps that of the blood and body generally, rises about 2° F. under tropical heat.
- 7th. The organs and functions of animal, like those of vegetable, life are affected by great changes of climate,—heat impairing the weight, strength, and health, *i. e.* the physique, at all ages and retarding growth in youth; while cold has an opposite effect.
- 8th. For obvious reasons these results vary with sex, temperament, size, &c.; and are most evident in the adult, decreasing towards either extreme of life.
- 9th. Collectively these changes are salutary, and meant to assimilate the various organs, functions, and body of the inhabitants of one zone to those of native races, to meet the requirements of the foreign climate, for which they are not, and perhaps never can be altogether, physiologically fitted.